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(54) **Optical-fibre telecommunications line with protection device for optical amplifiers.**

(57) In an optical-fibre telecommunications line comprising two terminal stations (1, 2), each having an optical-signal transmitter (T1, T2) and a receiver (R1, R2) operationally connected by an automatic protection device (51, 52) suitable for shutting down said transmitter (T1, T2) in the absence of a received optical signal, and respective optical-fibre lines (3, 4) connecting the transmitter of one station to the receiver of the other station and including at least one optical amplifier (5, 6, 7), at least one of said optical amplifiers is provided with a protection device (8) comprising means (11) for the detection of the presence of an optical signal at the output from the amplifier, operationally associated with means (19) for interrupting the emission of light located downstream of the said detection means (11) there are associatedsaid detection means (11), the interruption of the emission downstream determining the interruption of the emission along the entire line through the intervention of said automatic device (51, 52) for the protection of the terminal stations. With said detection means (11) there are associated filtering means (12) to limit the signal at the output from the amplifier to the alternating component of the same only, means (14) for detecting the peak of said alternating component, and means (18) for comparing the detected peak with a pre-set threshold, which operate said interruption means (19) to interrupt the transmission of the signal at the output from the amplifier when said detection means (11) detect a substantial absence of the signal at output.

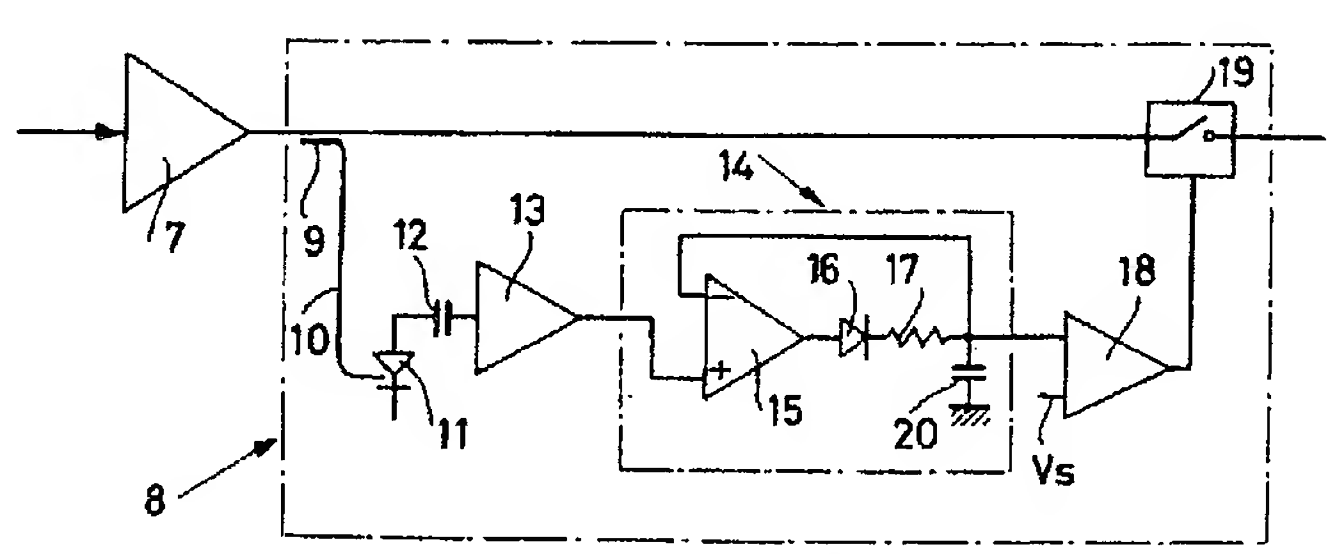

Fig.2

The present invention relates to an optical-fibre telecommunications line with protection device for optical amplifiers.

Telecommunications lines are known which use optical fibres to connect two terminal stations, each provided with a transmitter and a receiver suitable for allowing two directional communication.

In particular each station comprises a transmitter, which sends a light signal along an optical-fibre line destined for the opposite station, and a receiver suitable for detecting the optical signal arriving from the other station and to send it on to a user.

In the case wherein the terminal stations are at a great distance from one another several amplification units may be interposed along the line (say, a power amplifier in the proximity of the line input, one or more line amplifiers and a pre-amplifier immediately before the receiver at the line's extremity), which raise the power of the signal, so as to compensate for the attenuation to which the signal itself is subjected along the path.

Such amplification units may be constituted by so-called repeaters, which convert the signal from optical to electric, amplify it in the electrical form and reconvert it to a highpower optical signal and reintroduce it again into the line, or they may be optical amplifiers, which receive the signal in the optical form and produce its amplification while maintaining its optical form.

An example of such optical amplifiers is constituted by the active-fibre optical amplifiers, wherein a fibre containing a fluorescent substance receives the optical signal to be amplified and pumping light energy at a different wavelength, which determines a stimulated emission on the part of the fluorescent substance coherent with the optical signal to be transmitted, which is thus amplified.

Amplifiers of the abovementioned type are, for example, described in the European patent application No. 90202736.6 dated 15 October 1990.

A problem inherent in optical-fibre telecommunications lines relates to the protection of staff who repair or maintain the line.

In the case of an intervention on a line fibre, say, in the presence of a breakage thereof, it is necessary to avoid the presence of light emission in the fibre, because such emission could accidentally be directed toward the eyes of the maintenance staff, with consequent offence for their eyes.

In this respect the known art, as described, for example, in the ISPT standards [Upper Institute of Posts and Telecommunications], technical specifications No. 919, January 1989 edition, pages 135 - 144, lays down that in the case of the non-reception of the signal on the part of an exchange unit or of a line unit in one direction of transmission the transmitter operating in the opposite direction must be shut down. This in turn, determines the shutting down of the transmitter in the station upstream, eliminating the presence of light emissions in the interrupted line.

A unit operating in the manner described above is illustrated in the publication "SIEMENS TELECOMUNICAZIONI, Doc. 612-802/56-TM/I, edition 1, October 1989".

It has been discovered by the Applicant that an opticalfibre transmitter line with active-fibre optical amplifiers can be put in safety conditions and automatically restored by providing one or more amplifiers with respective protection means in a position of shutting down the amplifier itself in case the optical fibre upstream from the amplifier is interrupted.

More accurately, the above protection means comprise means for the detection of the presence of light energy at the input to the amplifier and associated means for causing the shutting down of the amplifier, which in the absence of light energy at the input to the amplifier are operated by said means for detection to interrupt substantially any emission of light energy on the part of said optical amplifier.

In this way, every time an interruption of the optical fibre takes place upstream from the optical amplifier, the consequent absence of light energy at the input to the same determines through the abovementioned detection means and associated control means the shutting down of the amplifier, which thus ceases to operate and above all to emit light energy at output.

Such interruption of the light energy at output is transmitted directly or through similar devices present in further amplifiers up to the terminal station, where devices of the traditional type are present to disactivate the transmitter operating on the return line, and then back the starting station, where a similar protection device of the traditional type disactivates the starting transmitter putting the entire line under safe conditions.

The line's functionality is on the other hand automatically restored after the interruption has been repaired, by switching on again a transmitter of one of the terminal stations, since each optical amplifier provided with such a protection device is again arranged to be in operational conditions as soon as the light energy at its input returns above the threshold level of said detection means.

The Applicant has also observed that the abovementioned protection is suitable in a number of types of line and power amplifiers, but that in some cases there are additional problems.

In particular, amplifiers exist applied in some positions along the line, such as, say, the so-called

«pre-amplifiers» for the application immediately upstream from a terminal line station, for which the power of the optical signal at inlet is particularly low.

In such cases the need has been identified of reducing to a minimum the attenuation of the signal upstream from the amplifier due to the introduction of safety devices, while at the same time avoiding the possibility that phenomena of spontaneous emissions of the active fibre may prevent the recognition of the absence of the signal at input, consequent on an operating anomaly.

According to the invention an optical-fibre telecommunications line has thus been accomplished, comprising two terminal stations, each having an optical-signal transmitter and receiver operationally connected by an automatic protection device suitable for shutting down said transmitter in the absence of a received optical signal, and respective optical-fibre lines connecting the transmitter of one station to the receiver of the other station and including at least one optical amplifier, characterized in that at least one of said optical amplifiers has a protection device comprising means for the detection of the presence of an optical signal at the output from the amplifier, operationally associated with means for interrupting the emission of light located downstream of the said detection means, the interruption of the emission downstream determining the interruption of the emission along the entire line, through the intervention of said automatic device for the protection of the terminal stations.

According to a preferred embodiment, said protection device associated with at least one optical amplifier also comprises filtering means to limit the optical signal at the output from the amplifier to just the alternating component of the same.

In this way the device for the protection of the amplifier operates, as has already been said, on just the alternating component of the signal at output from the amplifier itself. This allows the discrimination to be made between the presence of a transmitted optical signal and the presence of a continuous signal due to the spontaneous emission of the amplifier in the absence of the optical signal at input and thus to avoid non-interventions of the station's protection device.

It should lastly be considered that, by operating on the signal at output from the amplifier, an undesired attenuation of the optical signal upstream from the amplifier is avoided.

These and other features of the present invention shall be made evident by the following detailed description of an embodiment illustrated purely as a non-limiting example in the enclosed drawings, wherein:

Fig. 1 shows the overall diagram of an optical-fibre telecommunications line;

Fig. 2 shows the association of a protection device according to the invention with an active-fibre optical preamplifier included in the abovementioned line;

Fig. 3 shows the frequency spectrum of a possible transmitted optical signal;

Fig. 4 shows the frequency spectrum of the pre-amplifier's spontaneous emission;

Fig. 5 shows a preferred embodiment of an electronic amplifier with filtering condensers which may be used within the scope of the protection device according to the invention.

With reference to Fig. 1, in general an optical-fibre transmitter line comprises two terminal stations 1 and 2, each of which comprises a transmitter and a receiver, T1, R1 and T2, R2, respectively.

The transmitter T1 of the station 1 is connected to the receiver R2 of the station 2 through a first optical-fibre line 3 which can operate in one direction (from 1 toward 2) and the transmitter T2 of the station 2 is connected to the receiver R1 of the station 1 through a second optical-fibre line 4 destined to operate in the opposite direction (from 2 toward 1).

Along each line 3 and 4 there are several amplifiers, preferably constituted by active-fibre optical amplifiers.

Between them it is possible, on the basis of the needs of the line, to have a power amplifier 6, located in the proximity of the input terminal, and several line amplifiers 5.

In addition to them it is convenient to adopt preamplifiers 7 located in the proximity of the output terminal, suitable for raising the power of the optical signal up to a level adequate to the sensitivity of the receiver used, say, between -5 dBm and -15 dBm.

The terminal stations 1 and 2 are provided with automatic protection devices 51, 52 of the traditional type, which in the absence of a signal at the input to the receiver on a line cause the shutting down of the transmitter operating on the opposite line.

According to the present invention, as illustrated in Fig. 2, with one or more of the abovementioned amplifiers, in particular with the pre-amplifier 7, there is associated a protection device 8 which comprises a coupler 9, say, of the fused-fibre type with a shunted optical waveguide 10, located at the output from the pre-amplifier, an optical photodiode detector 11, a condenser 12 for the removal of the continuous component of the detected signal, an amplifier 13, a peak detector 14, a comparator 18 with reference threshold Vs and an optical switch 19 which the comparator 18 causes to open each time the peak detector 14 detects that an optical

signal at output from the pre-amplifier has an alternating component with a peak value lower than the threshold Vs.

The peak detector is, for example, constituted by an backfed operational amplifier 15, whose output is connected to the comparator 18 through a diode 16, and a resistance 20 and is connected to ground by a condenser 17.

As an example, the optical input signal of the preamplifier can have a level ranging from -35 dBm to -45 dBm and the pre-amplifier can, for example, provide a gain of 30 dBm, thus raising the optical signal to a level ranging from -5 dBm to -15 dBm.

The spontaneous emission of the pre-amplifier has indicatively a continuous level of the order of -10 dBm, thus comparable with the average power of the amplified signal.

Using a commercially available coupler 9 of the 1/10 type this takes 1/10 of the amplified optical signal and introduces a loss along the path to the line's optical output of some 0.5 dBm, negligible in practice as far as the transmission is concerned, providing the photodiode 11 with a signal with a level ranging from -15 dBm and -25 dBm, plus a spontaneous emission with a level equal to -20 dBm.

The optical signal taken by the coupler 9 is converted by the photodiode 11 into a corresponding electrical signal, from which the condenser 12 withdraws the continuous component and that is subsequently amplified by the amplifier 13.

The withdrawal of the continuous component allows the protection device to distinguish between the transmitted optical signal, which contains a substantial alternating component, and a spontaneous emission, having a continuous component of a high level, while its alternating component has an appreciably lower level.

As can be observed from the diagram of Fig. 3, a typical frequency spectrum at the output from an optical pre-amplifier in the presence of a transmitted optical signal which consists of a continuous component F1 (f=0), linked to the amplifier's spontaneous emission, that is, to noise, in a component with a numbered F2 frequency (f=fc) and in a substantially continuous spectrum F3, containing the transmitted information.

There is shown in Fig. 4 the frequency spectrum at the output from the pre-amplifier in the absence of a signal; such spectrum comprises a continuous component F1, linked to the amplifier's spontaneous emission, having a high intensity, substantially equal to that of the transmitted optical signal, and an almost flat (blank) ⟨⟨noise⟩⟩ spectrum F4, having a level appreciably lower than that of the signal.

Thus the elimination of the continuous component of the amplifier's emission allows the making of a comparison between the level of the F2 or F3 emission, in the presence of a signal, and the level of the F4 emission, that is, of noise in the absence of a signal, which has a value substantially lower than the previous ones, for example, at least lower than one tenth of the F2 or F3 levels, (with the typical power values indicated above) and can thus be distinguished easily from it.

The amplifier 13 amplifies only a limited band of the signal's spectrum. For example, it has been found convenient, with optical signals transmitted at 565 Mb/s, to use a frequency band from 20 kHz to 200 kHz.

The signal, filtered by the condenser 12, is amplified by the amplifier 13, for example up to levels around 1 volt, and then applied across the input of the peak detector 14, whose output is a continuous signal level, which varies, for example, from about 200 mV in the presence of the spontaneous emission only to at least 600 mV in the presence of a transmitted optical signal, even if of a low level (-45 dB).

This difference in level determines the triggering, in one direction or the other, of the comparator 18, whose intervention threshold can indicatively be placed around 400 mV.

When it recognizes the absence of a signal, the comparator 18 opens the optical switch 19, for example, constituted by a "Switch Module 11" produced by JDS Optics.

There is thus accomplished in this manner the function of interrupting the optical signal at the output from the preamplifier in the absence of an input signal, ensuring optical safety through the interruption of the optical emission downstream on the part of the pre-amplifier.

The receiver of the downstream terminal station, say, R2 in the case of an interruption of communications on line 3, upstream from the pre-amplifier, in the absence of an input signal interrupts in a traditional manner the transmission of the transmitter T2 associated with it, operating in the opposite direction, thus causing the information regarding the detected anomaly to reach the station 1 through the line 4.

The station 1 then, again in a traditional manner, interrupts the transmission of the related transmitter T1, thus placing in a safe condition (absence of optical emission) the line 3 along which the anomaly has occurred.

In the presence of other line 5 or power 6 amplifiers, the safety of the line as a whole requires that, in the absence of an input signal, these do not emit at output, ie, downstream, spontaneous emissions or noise, at a dangerous level.

The optical safety in the pre-amplifier is attained, with the equipment described, without introducing an optical loss upstream from the pre-

amplifier, as would be the case if the coupler 9 were to be inserted into the line upstream from the pre-amplifier itself.

The insertion of a coupler upstream from the preamplifier, in fact, even if it were to introduce a very limited loss, say, 1/10 or 1/20 of the optical power reaching the preamplifier, would reduce the signal to a very low level, such that the signal/noise ratio at the output from the preamplifier would be unacceptable.

It has, on the other hand, been discovered that, even in the presence of very low-level signals, typical at the input to a preamplifier, it is possible to detect the presence or the absence of a signal in the line, and thus the possible anomaly or interruption, and to bring the line to conditions of safety, by interrupting the emission of the preamplifier in the downstream direction.

When the line is about to be re-activated, when transmission in a terminal station is restored, on the other hand, the optical preamplifier, that has remained active, even with an interrupted emission, receives and amplifies the received optical signal and the protection device thus detects its presence; on the basis of this the optical switch 19 is immediately closed again, and transmission toward the receiver is restored without requiring local action.

There is shown in Fig. 5 a preferred embodiment of the amplifier 13 with related filtering means equivalent to the condenser 12 of Fig. 2.

The abovementioned amplifier is, for example, constituted by a cascade of operational amplifier stages 31-34 provided with respective feed-back resistances 35-38 which connect the respective outputs to the respective inverting inputs. The operational amplifier 31 has the non-inverting input connected to an intermediate node 39 between the photodiode 11 and a resistance 40 interposed between the same photodiode and ground, while the other operational amplifiers 32-34 have the non-inverting input connected directly to ground. The inverting input of the operational amplifier 31 is connected to ground through a resistance 41, while the non-inverting inputs of the operational amplifiers 32-34 are connected to the outputs of the operational amplifiers 31-33, respectively, through respective series of a capacity 42-44 and of a resistance 45-47. The capacities 42-44 constitute the filtering means otherwise indicated with 12 in Fig. 2.

Let us suppose, as an example, that the feedback resistances 35-38 are of 100 kohms, that the resistances 40, 41 and 45-47 are of 10 kohms, that the capacities 42-44 are of 100 nF and lastly that all the operational amplifiers have the same gain, set at 10.

The product of gain times bandwidth of the amplifier of Fig. 5 is thus of some 3 MHz and the upper band limit is thus of some 300 kHz for each stage and slightly less for four stages in cascade.

The cut-off frequency is given by the formula

$$f1 = \frac{1}{2\pi RC}$$

where R = 10 kohm and C = 100 nF, so that f1 is roughly equal to 160 Hz for each stage and slightly more for the three stages in cascade.

That shown in the drawings is obviously only one of the numerous possible embodiments of the present invention.

It must also be understood that the invention, though it is described with reference to optical amplifiers of the active-fibre type, in union with which it finds a preferred application embodiment, can be applied to any type of optical amplifier with similar requirements and characteristics.

Claims

1. Optical-fibre telecommunications line comprising two terminal stations (1, 2), each having an optical-signal transmitter (T1, T2) and a receiver (R1, R2) operationally connected by an automatic protection device (51, 52) suitable for shutting down said transmitter (T1, T2) in the absence of a received optical signal, and respective optical-fibre lines (3, 4) connecting the transmitter of one station to the receiver of the other station and including at least one optical amplifier (5, 6, 7), characterized in that at least one of said optical amplifiers has a protection device (8) comprising means (11) for the detection of the presence of an optical signal at the output from the amplifier, operationally associated with means (19) for interrupting the emission of light located downstream of the said detection means (11), the interruption of the emission downstream determining the interruption of the emission along the entire line through the intervention of said automatic device (51, 52) for the protection of the terminal stations.

2. Optical-fibre telecommunications line according to claim 1, characterised in that said means (11) for the detection of the presence of an optical signal at the output from the amplifier comprise an optical coupler (9), inserted immediately downstream from the amplifier, comprising a shunted optical waveguide (10) wherein there is coupled a fraction of the light

power at the ouput from the amplifier, means (11) for recognizing the presence of the signal in connection with said shunted optical waveguide (10), said recognition means (11) being also connected to means (18) for operating said interruption means (19).

3. Optical-fibre telecommunications line according to claim 2, characterised in that said optical coupler (9) is a fused-fibre optical coupler.

4. Optical-fibre telecommunications line according to claim 2, characterised in that said optical coupler (9) couples on the shunted waveguide (10) a fraction of the light power at the output from the amplifier ranging from a value of 1:1 to a value of 1:20 of the optical power at the output from the amplifier.

5. Optical-fibre telecommunications line according to claim 2, characterised in that said means (11) for recognizing the presence of a signal, in connection with said shunted optical waveguide (10), comprise a member (11) for converting the light power in the shunted optical waveguide (10) into corresponding electrical power, means for filtering (12) the continuous component of the output signal and means of detection (14) and comparison (18), in connection with said interruption means (19) of the light emission, to the means of detection and comparison (14, 18) there being sent only the alternating component of the signal.

6. Active-fibre optical amplifier for optical-fibre telecommunications line with protection device, characterised in that the protection device (8) comprises means (11) for detecting the presence of an optical signal at the output from the amplifier, operationally associated with means (19) for the interruption of the light emission located downstream from said detection means (11).

7. Optical amplifier with protection device according to claim 6, characterized in that the means (11) for detecting the presence of an optical signal at the output from the amplifier comprise filtering means (12, 42-44) to limit said signal at output to the alternating component of the same only.

8. Optical amplifier with protection device according to claim 6, characterized in that said means (11) for detecting the presence of an optical signal at the output from the amplifier comprise an optical coupler (9), inserted immediately downstream from the amplifier, having a shunted optical waveguide (10) wherein there is coupled a fraction of the light power at the ouput from the amplifier, means (11) for recognizing the presence of the signal in connection with said shunted optical waveguide (10) and control means (18) for operating said interruption means (19), in connection with said recognition means (11).

9. Optical amplifier with protection device according to claim 6, characterized in that the means (11) for detecting the presence of a signal comprise a member (11) for converting the light power in the shunted optical waveguide (10) into corresponding electrical power, filtering means (12, 42-44) of the continuous component of the signal at output and means for detection (14) and comparison (18), in connection with said interruption means (19) of the light emission.

10. Optical amplifier with protection device according to claim 9, characterized in that the filtering means (12, 42-44) of the continuous component of the signal at output comprise at least one condenser (12) interposed between the member (11) for converting the light power into electrical power and the means for detection and comparison (14, 18).

11. Optical amplifier with protection device according to claim 9, characterized in that said member (11) for converting electrical power is constituted by a photodiode connected to the extremity of the shunted optical waveguide (10).

12. Optical amplifier with protection device according to claim 9, characterized in that the means for detection and comparison (14, 18) comprise peak detection means (14) for detecting the peaks of said alternating component and means (18) for comparing the detected peak with a preset threshold.

13. Optical amplifier with protection device according to claim 9, characterized in that between the member (11) for converting the light power into electrical power and the means for detection and comparison (14, 18) there is interposed an amplifier circuit (13).

14. Optical amplifier with protection device according to claim 13, characterized in that at least one part of said amplifier circuit (13) is downstream from the filtering means (12, 42-44) of the continuous component of the signal at output.

15. Optical amplifier with protection device according to claim 13, characterized in that the amplifier circuit (13) is a an amplifier circuit with two or more stages (31-34) in cascade, the filtering means (12, 42-44) of the continuous component of the signal at output being constituted by at least one condenser (42-44) interposed between two or more of said stages (31-34).

16. Optical amplifier with protection device according to claim 13, characterized in that the amplifier circuit (13) uses a band from 20 to 200 kHz.

17. Optical amplifier with protection device according to claim 13, characterized in that the peak detection means (14) comprises a back-fed operational amplifier (15), with at output a diode (16), a resistance (20) and a condenser (17) to ground.

18. Optical amplifier with protection device according to claim 13, characterized in that it is an optical pre-amplifier, located immediately upstream of a receiver (R1, R2) of a terminal station (1, 2).

19. Optical amplifier with protection device according to claim 13, characterized in that it is an active-fibre optical amplifier, comprising one or more fluorescent dopants.

20. Protection device for an optical amplifier for an optical-fibre telecommunications line, in particular for an optical pre-amplifier, characterized in that it comprises means (11) for detecting the presence of an optical signal at the output from the amplifier, filtering means (12, 42-44) to limit said signal at output to the alternating component of the same only, means (14) for detecting the peak of said alternating component, means (18) for comparing the detected peak with a pre-set threshold and means of interruption (19) operated by said comparison means (18) to interrupt the transmission of said signal at output from the pre-amplifier when said detection means (11) detect a substantial absence of the signal at output.

21. Protection device according to claim 20, characterized in that the abovementioned detection means (11) are constituted by a photodiode (11) arranged at the output of a shunted optical waveguide (10) coupled to the output of the amplifier by means of an optical coupler (9).

22. Protection device according to claim 21, characterized in that said filtering means (12, 42-44) are constituted by at least one condenser interposed between said photodiode (11) and an amplifier (13).

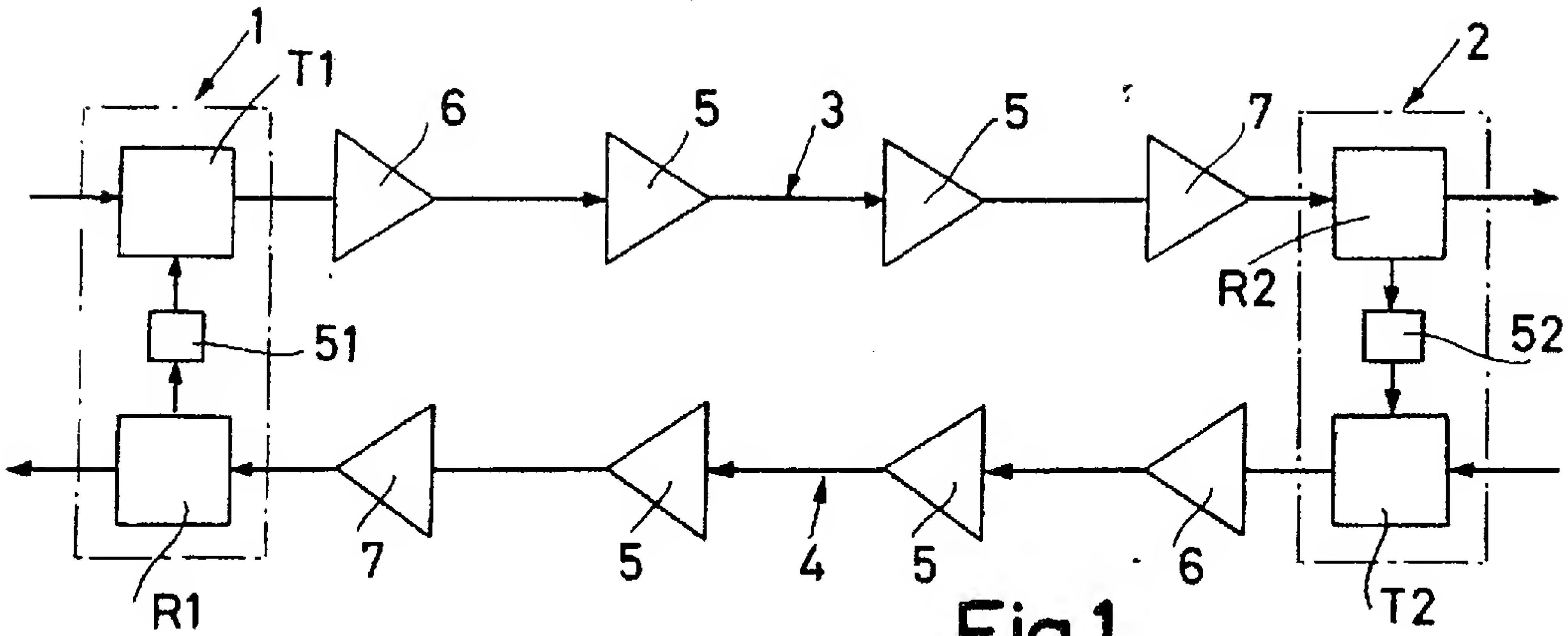

Fig.1

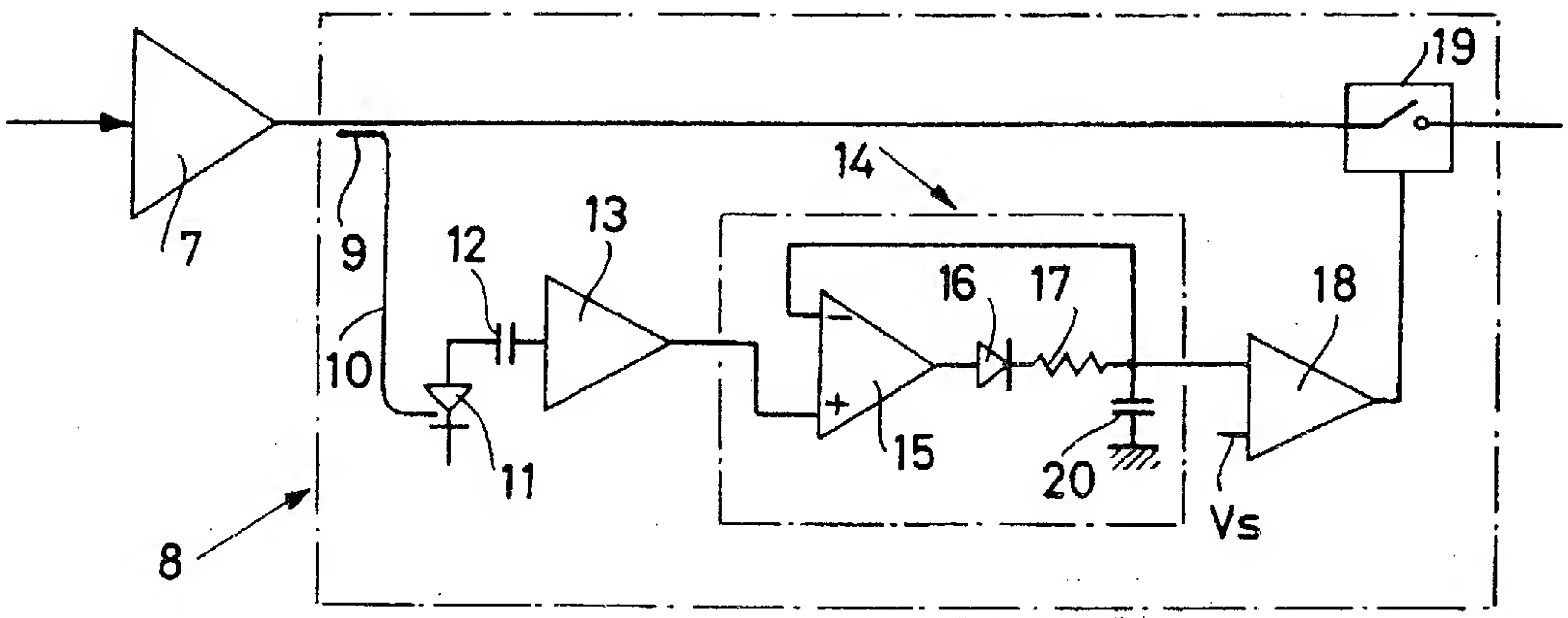

Fig.2

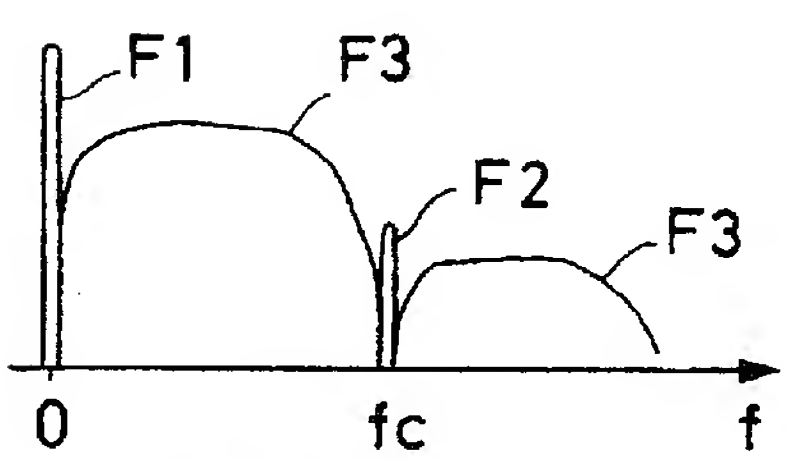

Fig.3

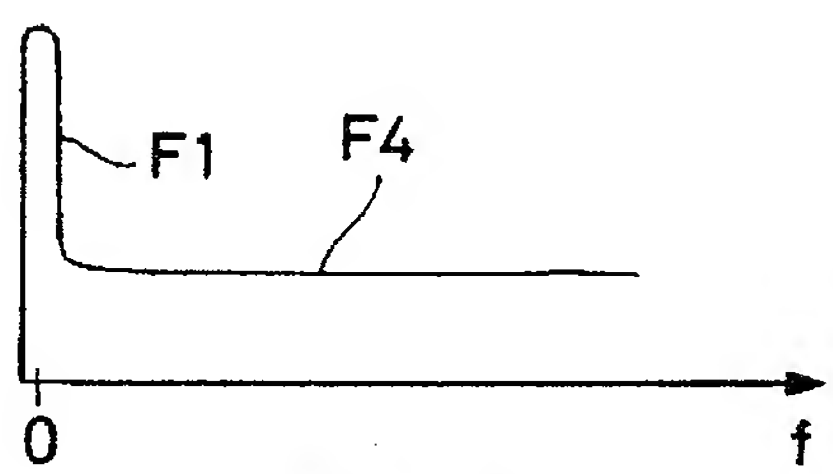

Fig.4

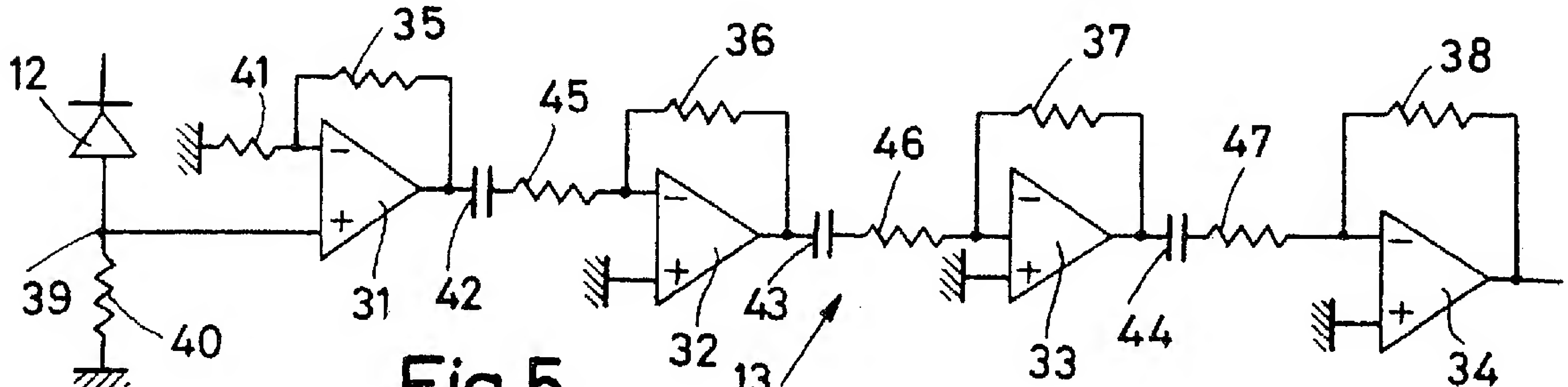

Fig.5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 20 0637

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y A	GB-A-2 051 355 (KOKUSAI DENSHIN DENWA) * page 1, right column, line 97 - page 2, left column, line 10; claim 1; figure 3 *	1 2,5,20,21	H04B10/16 H04B10/08
Y	US-A-4 247 956 (CHRISTIANSEN ET AL) * column 2, line 23 - line 39; claim 1 * * abstract *	1	
A	EP-A-0 331 304 (BRITISH TELECOMMUNICATIONS) * page 4, line 16 - line 44 * * abstract *	1,2,6,8,20,21	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H04B H01S

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	09 JUNE 1992	GOUDELIS M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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